

Subsidence and Levee Vulnerability in the Sacramento-San Joaquin Delta

Ben Brooks, *SOEST, U Hawaii*

Gerald Bawden, *USGS SW Regional*

Charles Werner, *Gamma Remote Sensing*

Deepak Manjunath, *SOEST, U Hawaii*

Noah Knowles, *USGS*

Joel Dudas, *Cal. Dept. Water Resources*

Dan Cayan, *Scripps/USGS*

Funded by the California Energy Commission PIER Program
through the California Climate Change Center



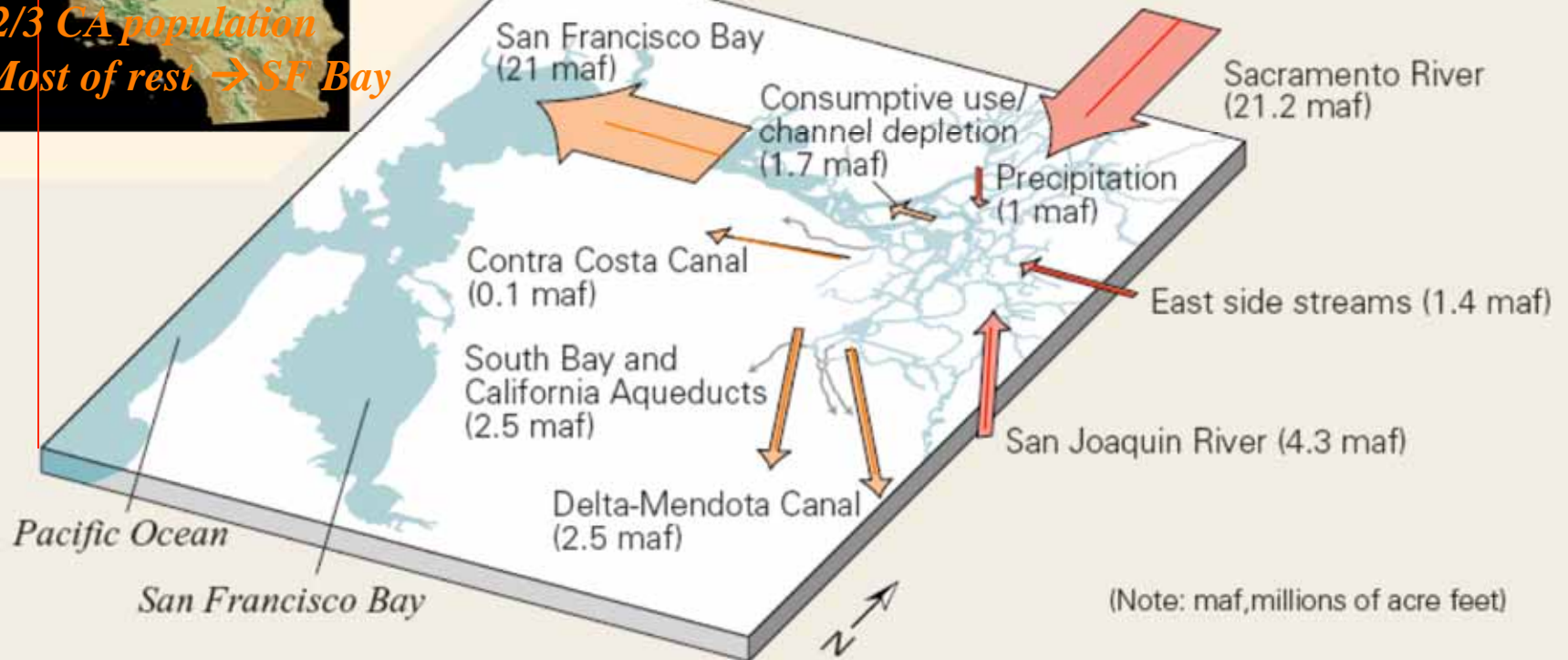
SACRAMENTO-SAN JOAQUIN DELTA & CALIFORNIA WATER BUDGET

ANNUAL OUTFLOW

- 25% inflow → CA water system
- Portion of drinking water for ~ 2/3 CA population
- Most of rest → SF Bay

ANNUAL INFLOW

- 40% CA land area runoff
- 50 % CA total streamflow



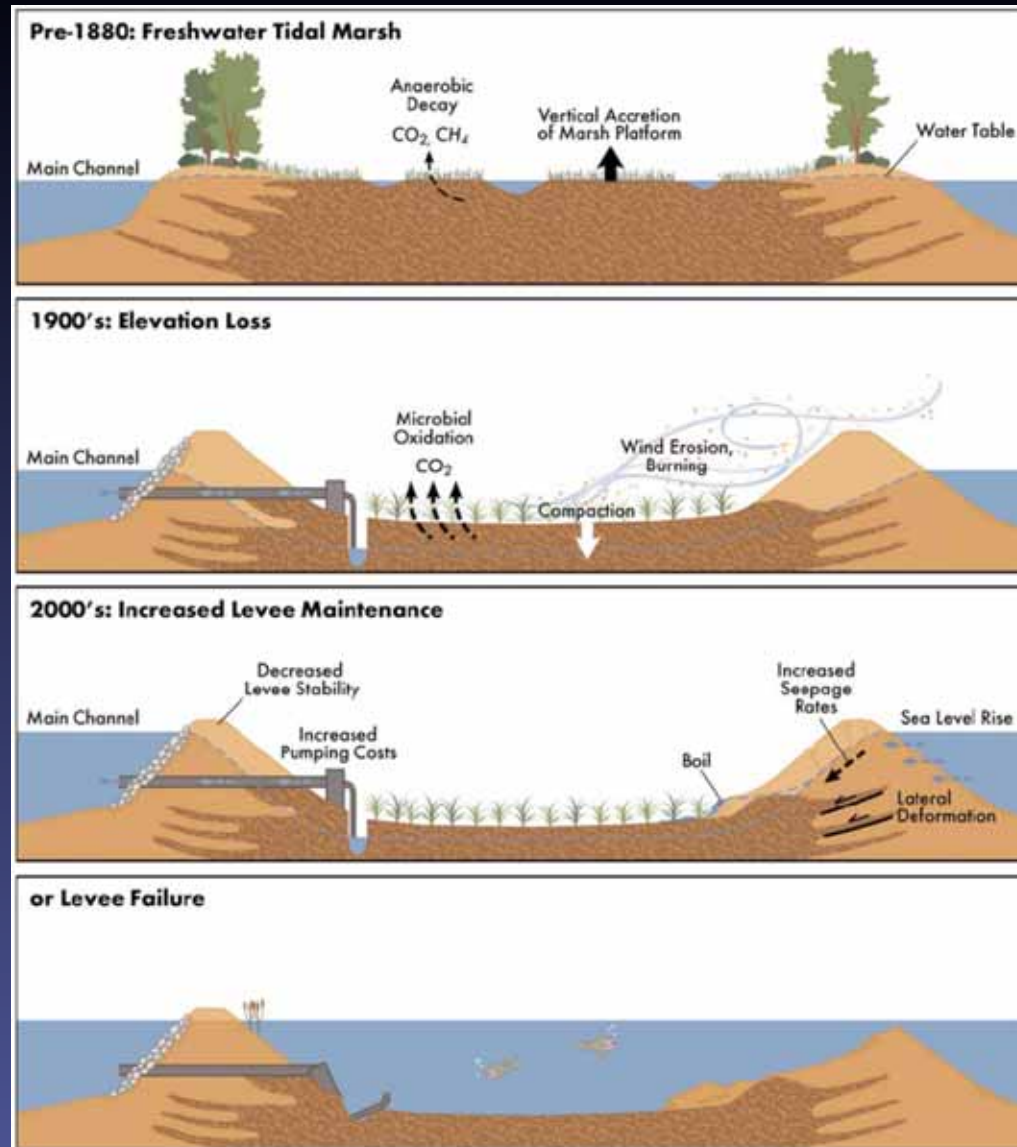
From Ingebreetsin et al., 2000; USGS report

ISLAND EVOLUTION, SUBSIDENCE, AND LEVEES

Island draining for agricultural purposes → compaction and elevation loss.

Sea level rise, ageing levees, continued subsidence →

risk to fresh water quality

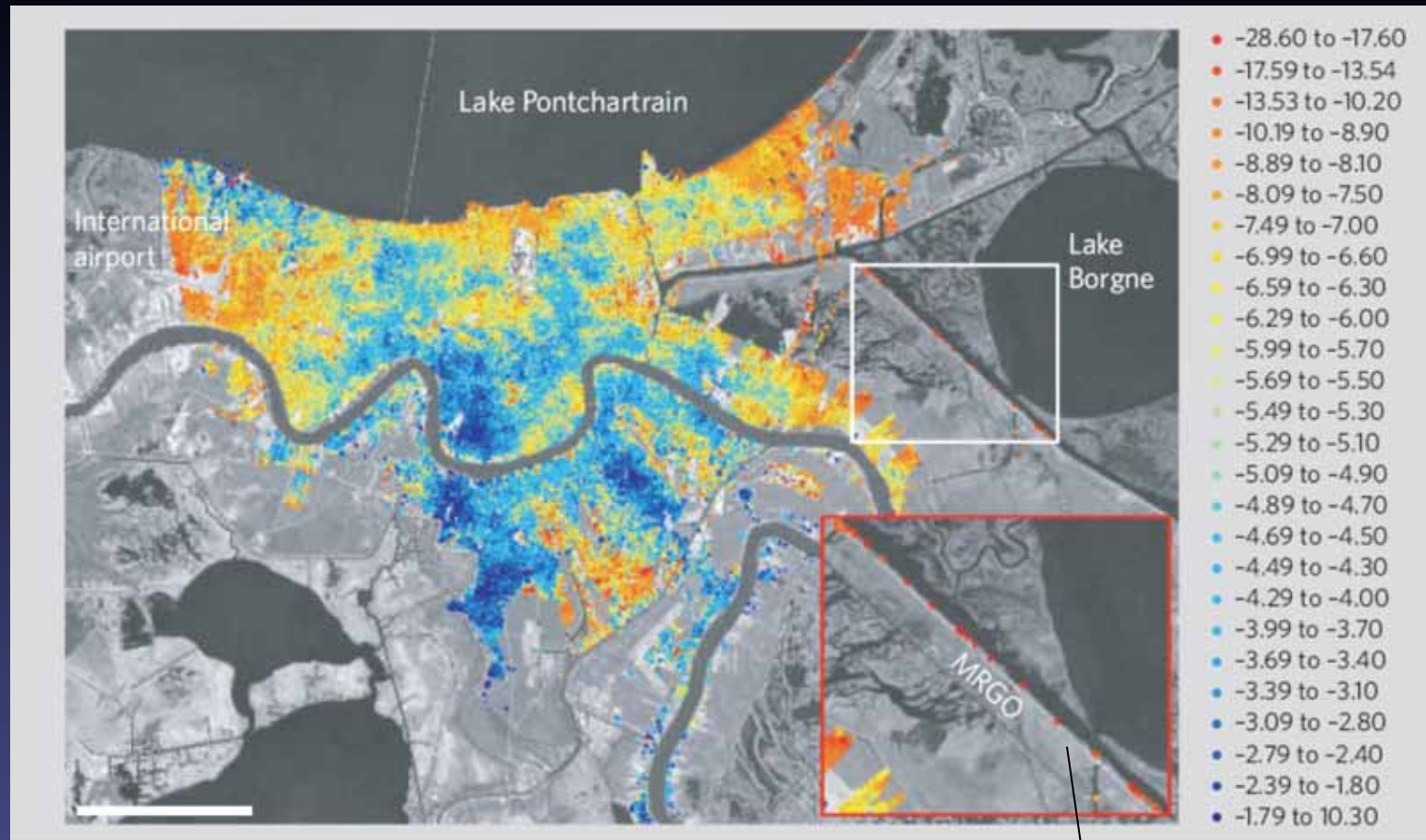


Levee Failure Modes

- differential subsidence
- overtopping (largely un-studied)

From
Mount and Twiss, 2005

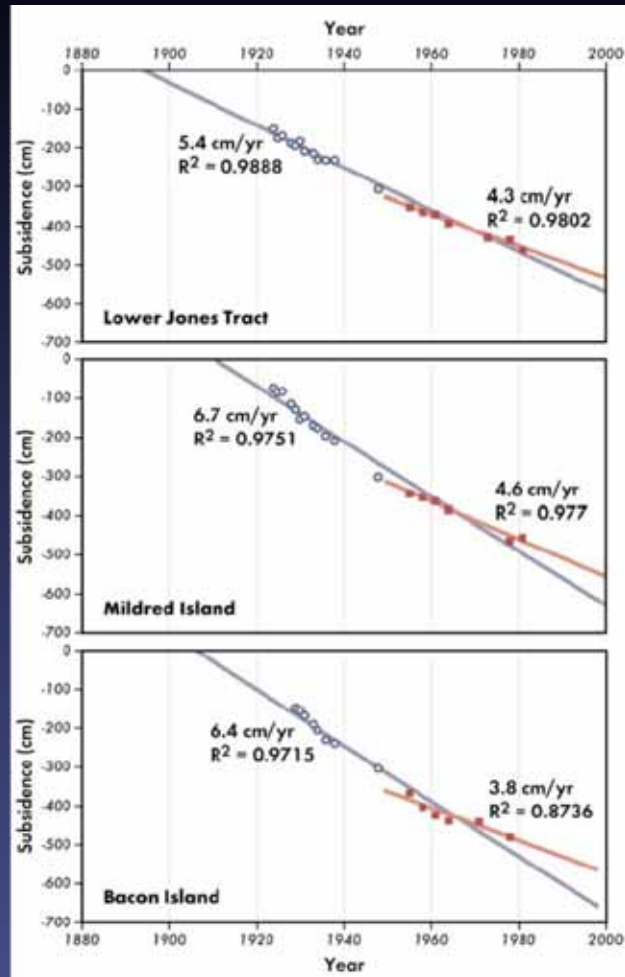
INSAR AND LEVEE STABILITY: HURRICANE KATRINA



From Dixon et al., 2006

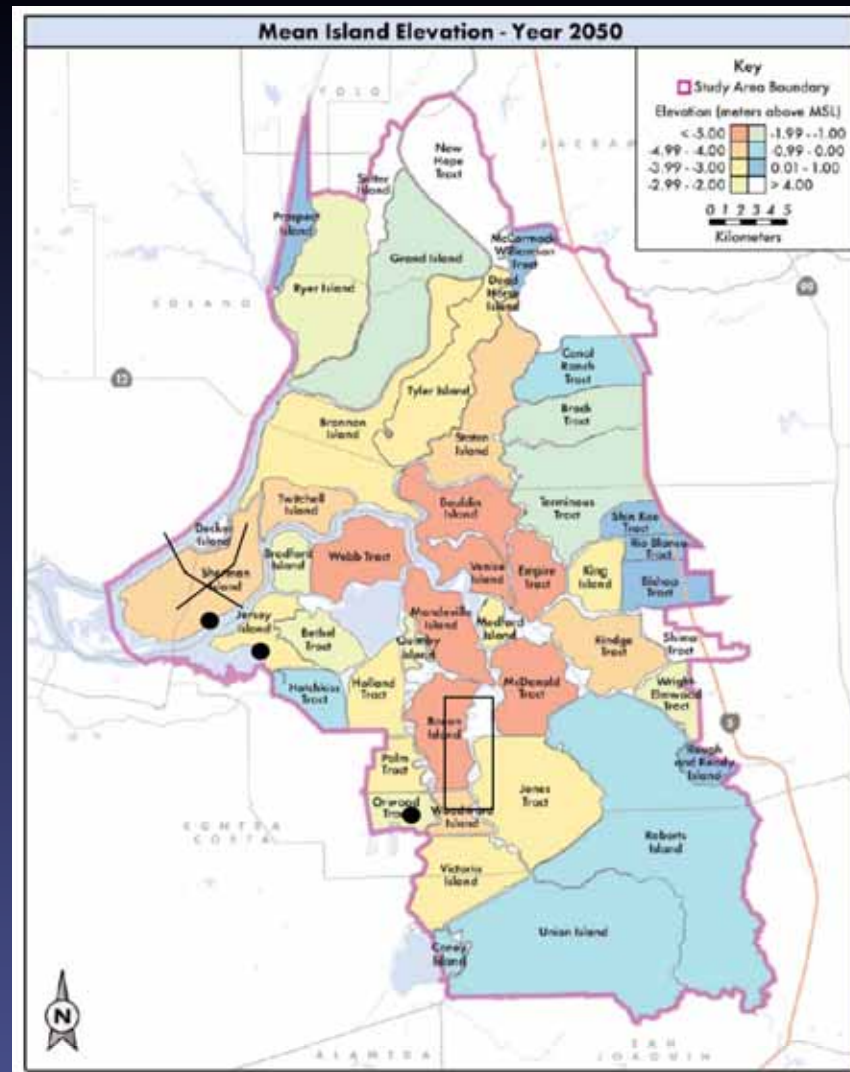
Levee failures from overtopping correlated with highest subsidence rates

50 YEAR PROJECTION



From Mount and Twiss, 2005

Based on leveling & point measurements
(Deverel & Rojstaczer, 1996; Rojstaczer & Deverel, 1995) and regional topographic analysis



NEED FOR SYNOPTIC, HIGH RESOLUTION
MEASUREMENT/ MONITORING
OF DELTA SUBSIDENCE

SPACE-BASED GEODESY:

GPS AND INSAR (SYNTHETIC APERTURE RADAR INTERFEROMETRY)



GPS network:
continuous operation

3 components
(NEU)



SAR
satellite:
repeat orbits

1 component
(LOS – line of sight)

- *mm-scale resolution*

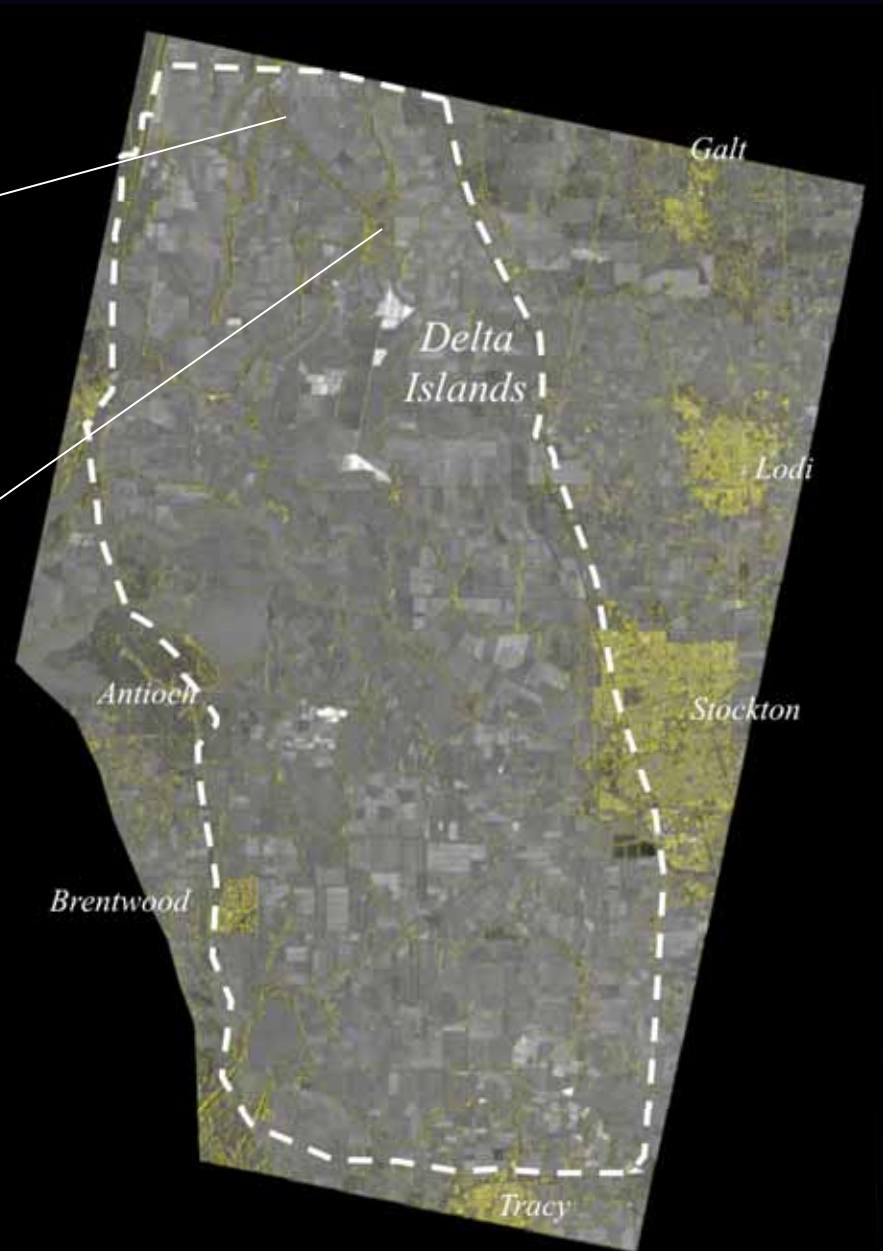
- *errors: atmospheric and ionospheric*

GPS: temporal coverage
InSAR: spatial coverage

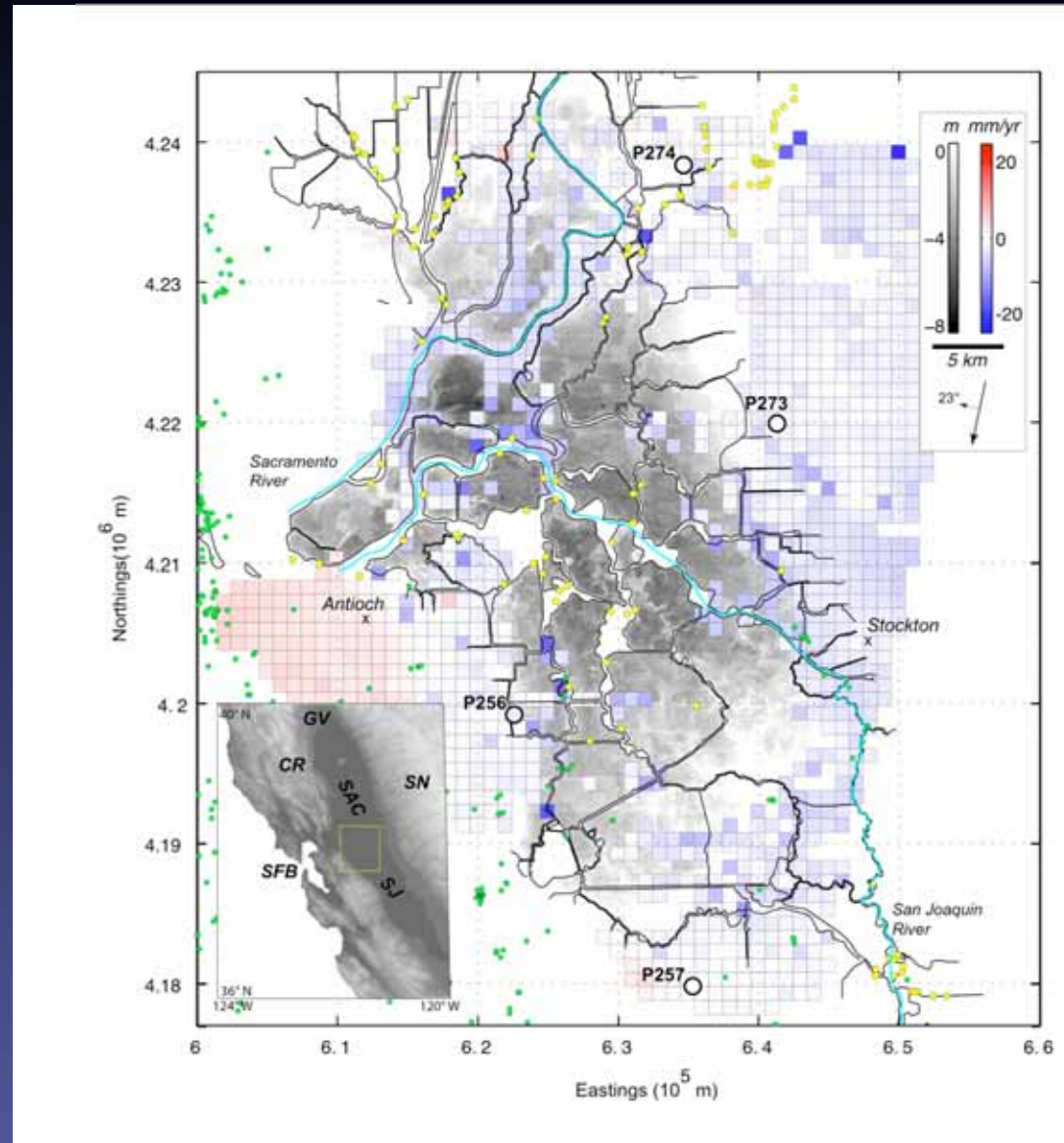


DELTA PSINSAR TARGETS

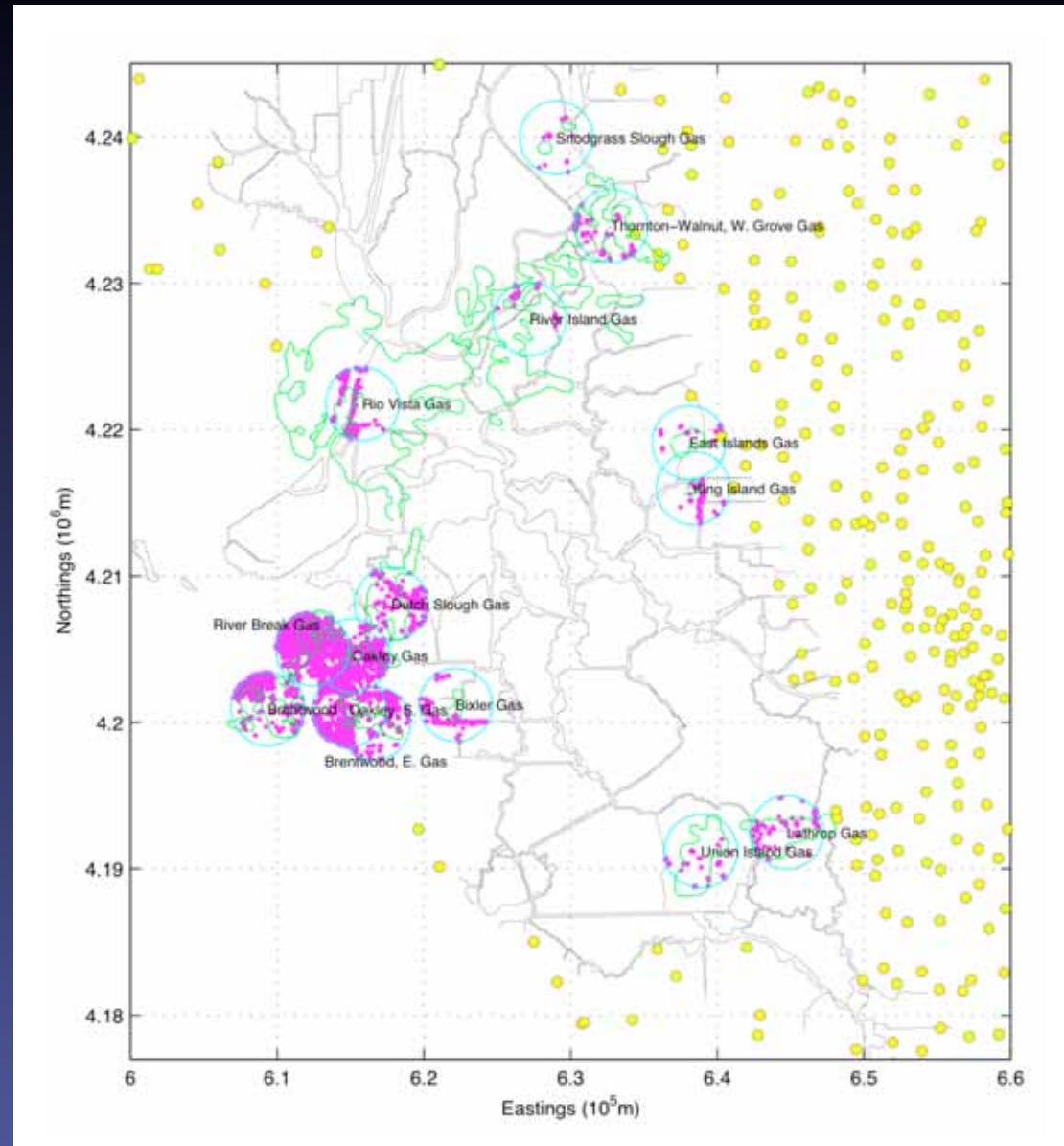
- 38 ERS-1 images (1995-2000)
- Descending Orbits
- > 100,000 PS targets



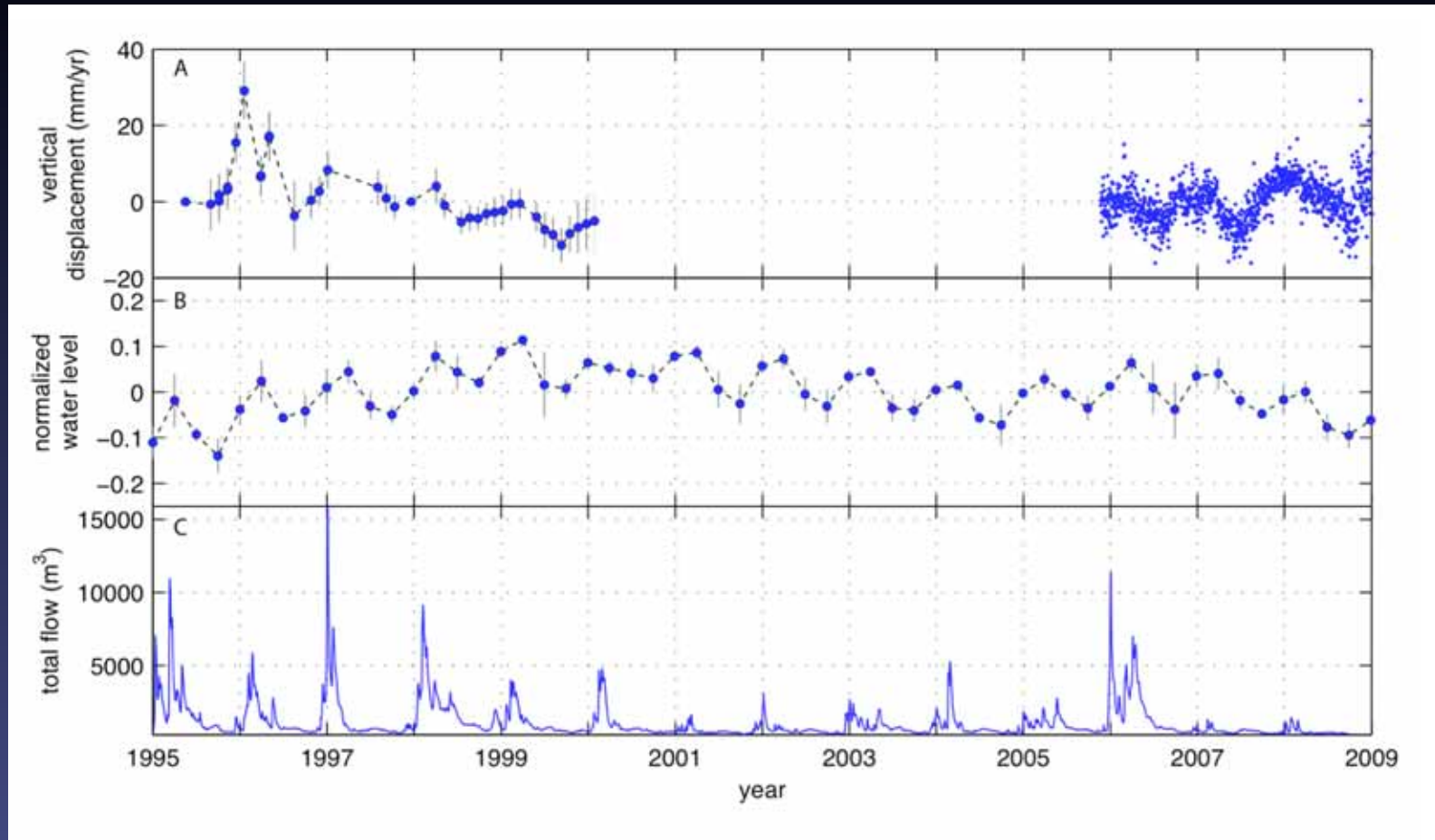
AVERAGE VERTICAL MOTION (1995-2000)



GAS FIELDS & GROUND WATER WELLS

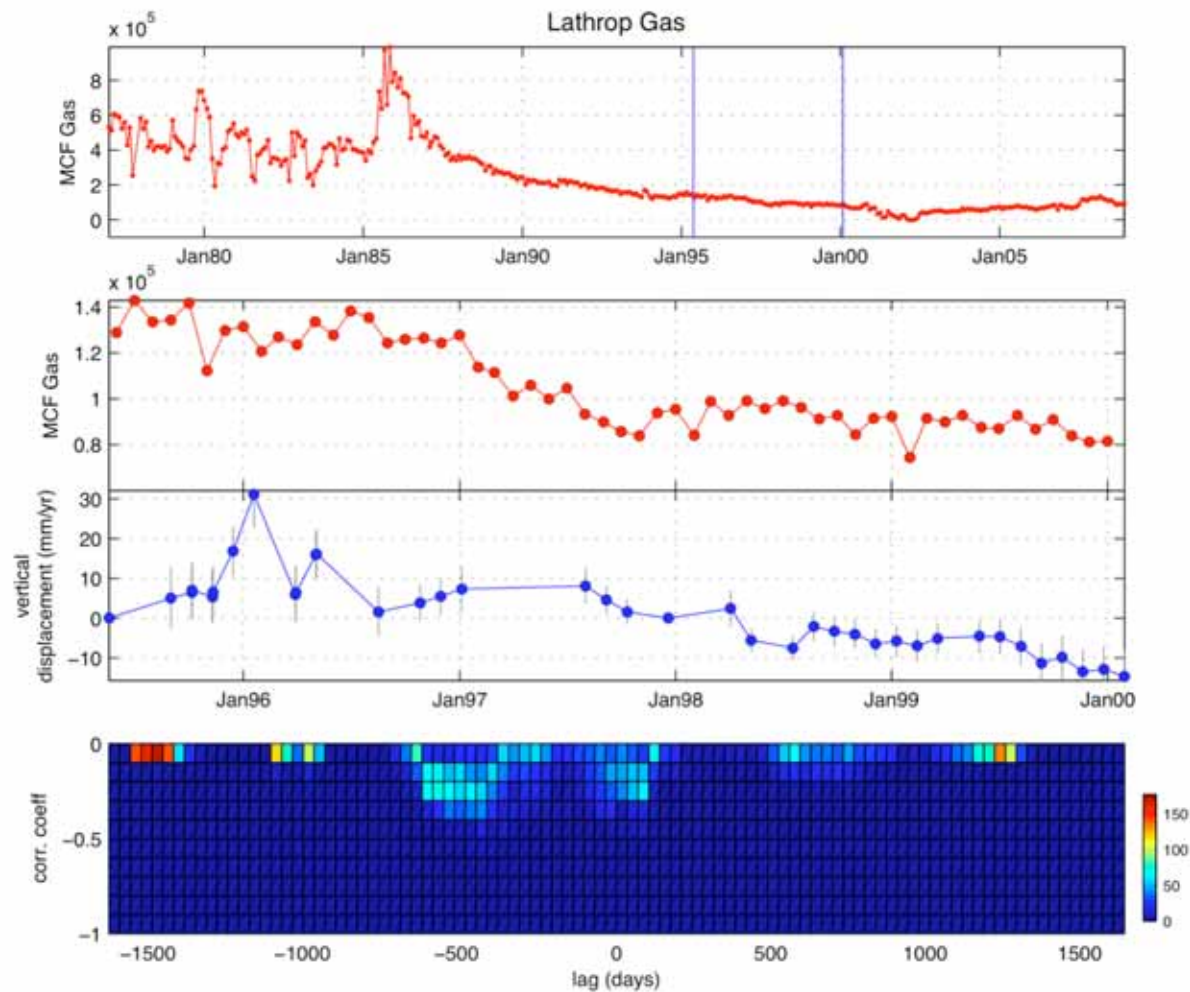


TIME SERIES

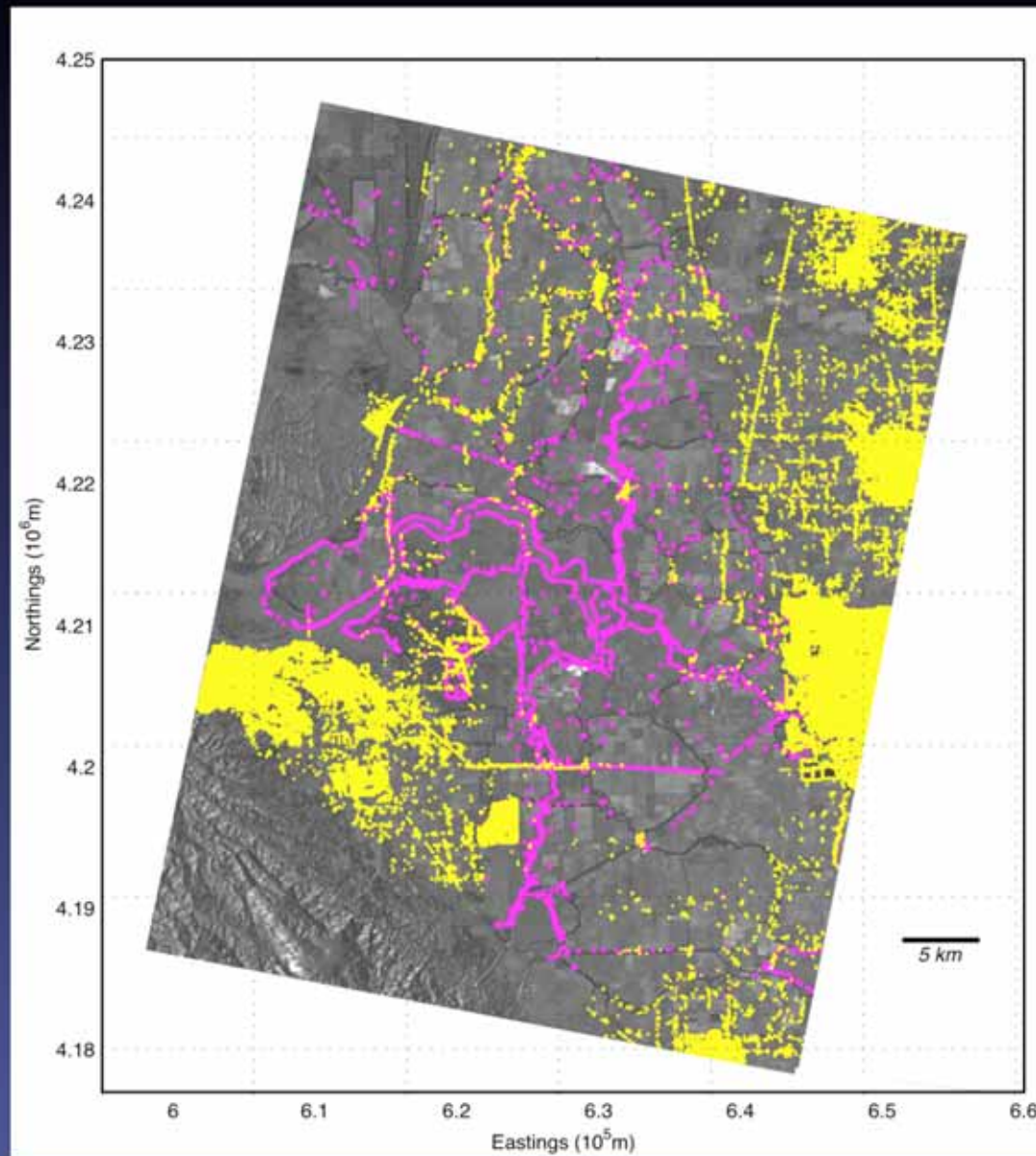


- seasonal correlation but no average rate contamination from hydrologic sources

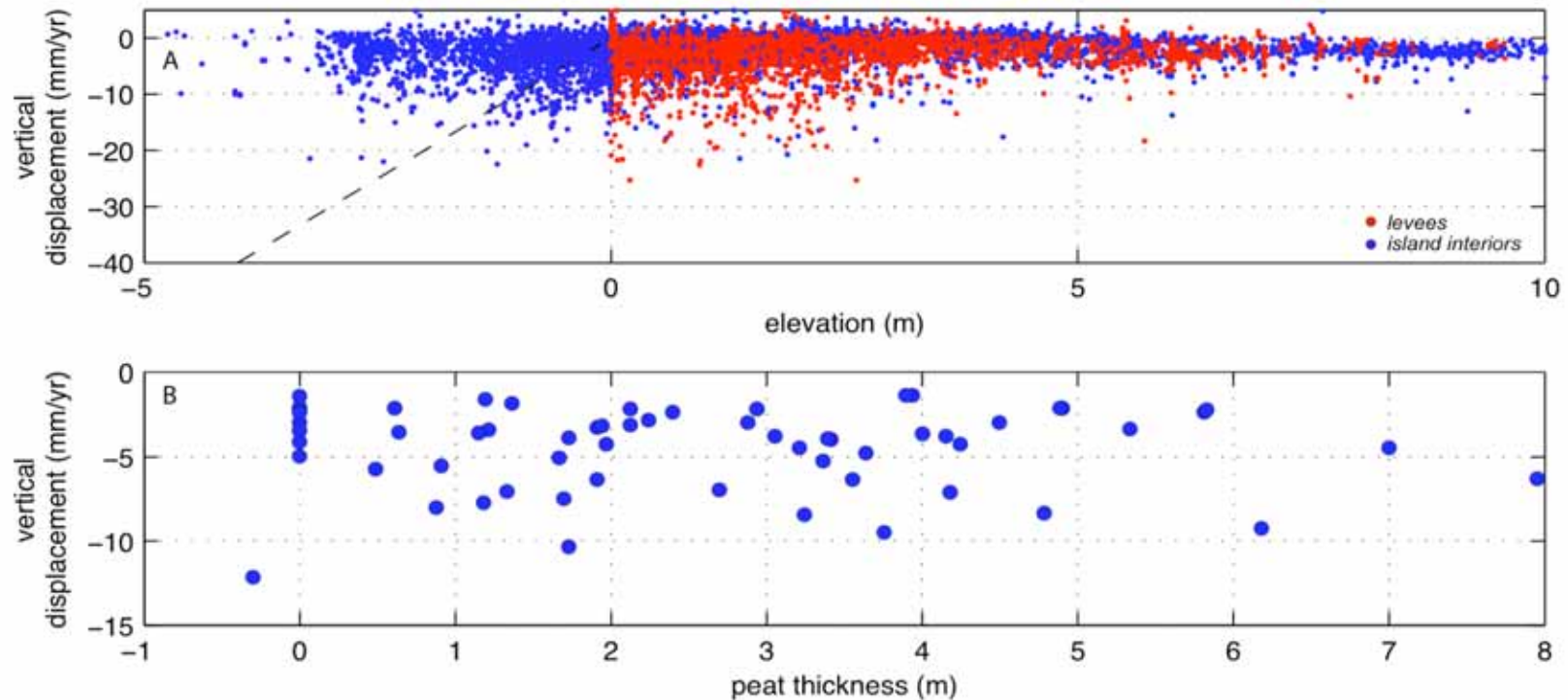
CROSS-CORRELATION ANALYSIS



PEAT THICKNESS MEASUREMENTS



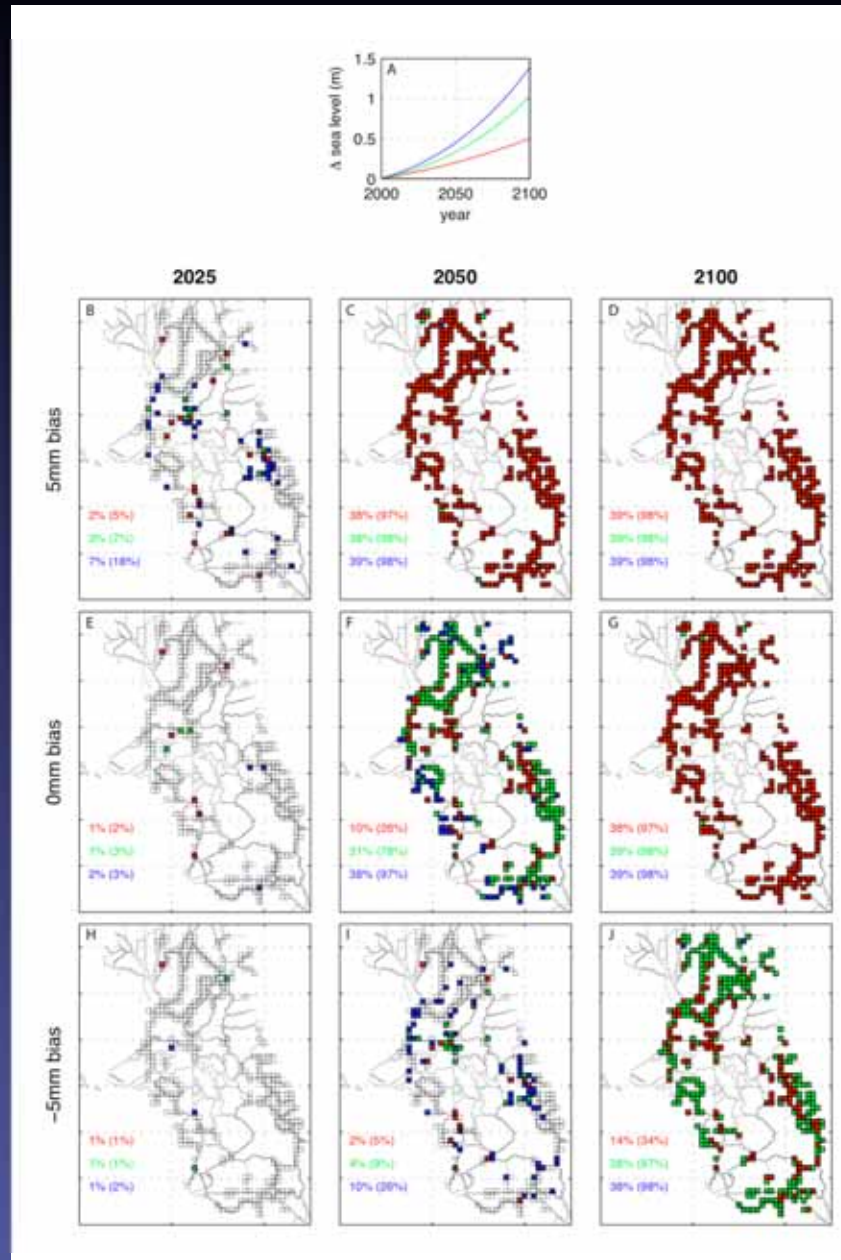
ELEVATION & PEAT THICKNESS



-InSAR technique not sensitive to peat-related differential subsidence but records more regional signal which we infer to be the continued compaction of the Delta sedimentary column

- Similar rates to those modeled and observed in the Mississippi Delta

PROJECTIONS



CONCLUSIONS

- InSAR provides synoptic subsidence measurement throughout the Delta at rates of 5-20 mm/yr
- Data are not contaminated by hydrologic nor hydrocarbon-related signal
- Data are not sensitive to peat-related differential subsidence
- InSAR subsidence likely records continuing compaction of Holocene Delta sediments
- Projections including sea-level rise indicate large-scale overtopping threat in the 21st century